ELECTROKINETIC EFFECTS IN THE FILTRATION OF WATER

BY

HASSAN FARID ZAGHLOUL

B.S., Fouad I University, Egypt, 1940
M.S., University of Illinois, 1947

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENGINEERING
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1950

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ELECTROKINETIC EFFECTS IN THE FILTRATION OF WATER

I. Introduction

A. The Problem

It has been discovered that head loss increases during the filtration of water regardless of its clarity before filtration. This discovery led to the thought that electrokinetic phenomena might play a part in the building up of head loss, especially during high rates of filtration. The main purpose of this study was to determine whether electrokinetic phenomena are involved in the filtration of water or not, and to discover some of their effects on the clogging of filter media during filtration.

There is an initial head loss with a given rate of filtration and a given medium. The initial head loss is observed at the beginning of the run when the filter medium is clean. This initial head loss has been explained from the hydraulic point of view.

The increase of head loss during the filter run needs more attention. This increase of head loss during filtration is attributed mainly to clogging of the filter by the suspended materials which adhere to the walls of the narrow interstices through which the water percolates. It might be more clearly understood if it is said that these suspended materials decrease the porosity of the filter media and increase their restistance to the flow of water. This hypothesis has been the main concern of the investigators who are interested in studying the theory of filtration. The results of many investigations in this field have been published since filtration became important in water treatment. Few of the investigators paid much attention to the fact that the head loss through filter media also increases during the run even with fairly clean or prefiltered water.

B. Need for the Study

A survey of the literature dealing with filtration reveals many investigations on the theory. Although most of these are valuable contributions from the theoretical point of view, they give little help from the practical point of view. It is difficult at the present to find a clear and simple relation among the factors affecting the flow of water through filter media. It is believed that a study of some of these factors, based on laboratory tests, may lead to the discovery of the relationship.

Electrokinetic phenomena are newly discovered factors in water filtration. Although many investigators have added to our knowledge of electrokinetic effects, their conclusions are not confined to our problem because their work was confined mainly to industrial processes, and their tests were made on membranes and continually built-up filter cakes. It was, therefore, important to study electrokinetic effects, and develop knowledge of such new factors in the filtration of water. It is hoped that this investigation would help improve filter design and operation. It is also anticipated that this investigation will stimulate other investigators to further our knowledge about these new factors in the hydraulics of filtration.

C. Delimitations

The water used in this investigation was distilled water. Chemicals were added to the distilled water in some tests. Distilled water was used to eliminate the effect of dissolved substances on electrokinetic phenomena. Theoretically this water is expected to be free from any mineral content, but practically the distilled water of our laboratory contains a rather small amount of copper (0.016 p.p.m.) that reaches it from the still. This small content of copper is unavoidable with the kind of still used. As long as the same source of water was used for all the tests in a series, the amount of copper was fairly constant in all the tests. The distilled water also dissolved some carbondioxyde and other gases from the atmosphere which made its pH usually below 7.

Whenever any chemical, such as chloramine-T, was added to the distilled water, the amount of this chemical was accurately measured in order to maintain an unchanging quality of the water. Three filter media were used in this investigation. These media were diatomaceous earth, sand, and porous stainless steel.

II. Experimental Approach

A. General

The plan of the experiments conducted during this investigation included the following objectives:

1. To demonstrate that some of the electrokinetic phenomena, namely the streaming potential, the electro-osmosis, and the electrophoresis, contribute to the increase of head loss across the filter during the filtration of water.
2. To determine some of the factors that affect these electrokinetic phenomena in the field of water filtration.
3. To determine what can be done to eliminate or decrease the effects of electrokinetic phenomena in the filtration of water.

B. Demonstration of the Electrokinetic Effects

Two methods were adopted to prove that a part of the head loss across the filter during filtration is due to streaming potential and electro-osmosis. The first method was based on a hypothesis that the streaming potential and the electro-osmosis retard the flow of water through the interstices of the filter medium. Putting this last statement in terms of head loss, it can be stated that the streaming potential and the electro-osmosis increase the head loss across the filter. If the streaming potential is dissipated, the electro-osmosis is reduced or stopped; hence the head loss across the filter de-

creases. So the first attempt to demonstrate the existence of the streaming potential and the electro-osmosis during filtration of water was to observe the decrease of the head loss across the filter after dissipation of the streaming potential. The dissipation of the streaming potential was accomplished by stopping the flow through the filter for a period of rest. The decrease of head loss across the filter, after this rest period, was observed with each of the three filter media used. These media were diatomaceous earth, sand, and porous stainless steel.

The second method planned for demonstrating the existence of streaming potential and electro-osmosis in the filtration of water was the direct measurement of the difference in electrical potential of water upstream and downstream from the filter. The results of this measurement proved that the streaming potential is created during filtration of water.

C. Factors Affecting Electrokinetic Phenomena

Some factors affecting electrokinetic phenomena during the filtration of water were studied. These factors are prechlorination of water, grain size in sand filters, rate of flow through the filter media, and the application of an external electric current.

III. Conclusions and Recommendations

A. General

It has been demonstrated through this investigation that electrokinetic phenomena play a considerable part in building up the head loss across a filter during the filtration of water. These electrokinetic phenomena are streaming potential, electro-osmosis, and electrophoresis. Direct measurement of the difference in potential across a filter was accomplished.

B. Prechlorination

Prechlorination proved to reduce the electrokinetic effect

on the rate of increase of head loss during filtration. This fact is attributed to the effect of chlorine on bacteria and on the electrical conductivity of water. An explanation of the bacterial clogging of filters is given. How chlorine eliminates this bacterial clogging is discussed. The effect of electrical conductivity on the rate of increase of head loss across a filter is referred to briefly. It is recommended that chlorine be added to the water immediately before filtration in all water treatment plants to decrease the electrokinetic effects during the filtration of water.

C. Grain Size of Sand

The effect of the grain size of sand on the electrical clogging of sand filters was studied. Two significant sizes of sand were discovered. They are the upper critical size and the lower critical size. The upper critical size is the size above which electrokinetic phenomena have no effect on the head loss through a filter and below which, to the lower critical size, the rate of increase of head loss increases with decreasing size of sand. The lower critical size of sand is the size above which, to the upper critical size, the rate of increase of head loss decreases with increasing size and below which the rate of increase of head loss starts to decrease with decreasing size of sand. In this investigation, at the rate of filtration of 10 g.p.m. per sq. ft., using distilled water, the upper critical size and the lower critical size were found to be 0.323 mm. and 0.193 mm., respectively. Whether these two critical sizes remain constant with different rates of filtration was not determined in this investigation.

It is recommended, as a result of the discovery of the upper critical size, that the minimum grain size of sand in rapid sand filters should not be less than the upper critical size. In other words, the minimum acceptable grain size in rapid sand filters should be the upper critical size. The application of this recommendation in practice will reduce the electrokinetic effects in rapid sand filters, and thus lengthen the filter runs.

D. Rate of Flow

The effect of rate of flow on the electrical clogging of filters was studied for both diatomite filters and sand filters*. In both types of filters, the electrokinetic effect on the head loss across the filters increases with increasing rate of flow. The rate of increase of head loss through the sand filters as well as diatomite filters is comparitively large for rates of filtration higher than 10 g.p.m. per sq. ft., while it is comparatively small for rates of filtration lower than that particular rate. It is therefore recommended that the rate of filtration in practice should be selected to keep the velocity through the filter interstices less than the velocity of distilled water through the interstices of the filter when passing at a rate of filtration of 10 g.p.m. per sq. ft.

E. Application of External Electric Current

The application of an external electric current was found successful in breaking down the electrical clogging of filter media. It is believed that the use of electric current may find some industrial application in the field of filtration. The purposes of such applications might be to overcome the electrical clogging of filter media thus lengthening the filter runs for the same available head, or to break down the electrical clogging of deep-well screens thus eliminating the expense of chemical treatment.

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* Sand used in this study was composed of heterogeneous grain sizes less than the lower critical size.

VITA

Hassan Farid Zaghloul was born in Egypt, December 5, 1916. After receiving his early education in primary and secondary public schools, he was enrolled in the College of Engineering of Fouad I University in Cairo, Egypt. He completed his undergraduate work at this university and obtained the degree of Bachelor of Science in Civil Engineering in June, 1940. He then worked as a civil engineer for the General Department of Municipalities in the Ministry of Public Health, Cairo, Egypt. During his service in the Ministry of Public Health, he was appointed resident engineer for the project of enlarging and rebuilding Farouk Highway. This highway connected the city of Suez to Port Tawfik on the Red Sea. In 1944, he was engaged by the American University in Cairo, Egypt, to correct written papers in the water works course offered by correspondence to the American soldiers.

In November, 1945, the author was selected by the Ministry of Public Health and the Ministry of Education in Egypt to be sent to the United States of America to receive intensive training in the field of Sanitary Engineering. Upon his arrival in the United States of America he worked for Alvord, Burdick and Howson, Consulting Engineers in Chicago, Illinois, from May to September, 1946.

He began his graduate study at the University of Illinois in September, 1946. In June, 1947, he obtained the degree of Master of Science in Sanitary Engineering. Since that time, he has continued his graduate work at the University.

The author was awarded a fellowship in the Civil Engineering Department from February to June, 1949. From June to September, 1949, he was appointed as a half-time graduate research assistant in the same department. He is a member of the Sigma Xi honorary society and Mu San honorary fraternity.